ARL-TN-0871 ● Feb 2018

US Army Research Laboratory

100 Years of Army Artillery Meteorology: A Brief Summary

by J L Cogan

NOTICES

Disclaimers

ARL-TN-0871● Feb 2018

US Army Research Laboratory

100 Years of Army Artillery Meteorology: A Brief Summary

by J L Cogan
Computational and Information Sciences Directorate, ARL

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED (From - To)
February 2018	Technical Note	October 2017-January 2018

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
100 Years of Army Artillery Meteorology: A Brief Summary	
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	**5d. PROJECT NUMBER**
J L Cogan	
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	**8. PERFORMING ORGANIZATION REPORT NUMBER**
US Army Research Laboratory ATTN: RDRL-CIE Aberdeen Proving Ground, MD 21005-5067	ARL-TN-0871
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Personnel in armies worldwide have been aware for centuries that the atmosphere may affect the trajectories of all types of projectiles from arrows to artillery. At longer ranges, meteorological error may contribute up to two-thirds of the entire trajectory error budget. This short report briefly summarizes developments in land-based artillery meteorology over approximately the last 100 years in the United States, with a limited reference to related developments in the United Kingdom.

15. SUBJECT TERMS

artillery meteorology, artillery meteorology history, meteorological observation systems, meteorological model applications, operational meteorological systems

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					James L Cogan
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (Include area code)
Unclassified	Unclassified	Unclassified	SAR	14	301-394-2304

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Contents

List of Figures

1. Introduction

Personnel in armies worldwide have been aware for centuries that the atmosphere may affect the trajectories of projectiles launched from weapons, whether catapults, firearms, or artillery of all sizes. At longer artillery ranges, meteorological (MET) error currently contributes up to two-thirds of the total trajectory error budget (Jones 2011; Wahl 2006). This report briefly summarizes developments in artillery meteorology for land-based systems over approximately the last 100 years in the United States (US), with a limited reference to related developments in the United Kingdom (UK).

2. World War I to Start of World War II

With the increasing ranges and apogees of artillery leading into World War I (WW1), the need to know upper air winds and density (pressure and temperature) became ever more apparent. Significant progress was made during WW1 (Pedgley 2006). Pilot balloon (pibal) ascents were new at that time but were widely used to obtain winds up to about 4000 ft (~1220 m) above the ground. An operator tracked the pibal via a theodolite, recording the elevation and azimuth angles, then used the known rate of ascent to calculate the winds from those observations. For the needs of longer range artillery, aircraft could provide measurements up to around 14,000 feet (~4270 m). The general headquarters prepared wind forecasts and sent them to forward areas.

Between WW1 and World War II (WW2) advances included radiosonde observations (RAOBs) for upper air measurements which, in the continental US, replaced aircraft based soundings by the late 1930s. Although the Navy, and to some extent the Army later in the period, were somewhat better off than the civilian weather service, efforts to integrate new methods of analysis and forecasting were hampered by severely restricted budgets for meteorology during the Depression years (Harper 2008). The Army recognized the need for meteorological information for artillery, and other areas such as aviation and defense against poison gas. However, the resources to provide the required information remained very low from the end of WW1 to the period immediately before WW2.

3. World War II

During WW2, balloon-borne radiosondes as well as pibals were widely used to obtain upper-air data for Army artillery and the Army Air Force. In addition, radar tracking of sondes and pibals came into use later in the war, providing the ability

to track balloons to higher altitudes and in cloudy conditions. In 1943, equipment called the "Radio Set SCR-658" was fielded for upper-air soundings, and although it had some weaknesses it was the forerunner of later rawinsonde systems such as the CMD-1 (Leviton and Hafford 1970). The SCR-658 provided upper-air wind data and data for computation of density. These atmospheric data were processed manually into a format for use in the artillery fire-control center.

4. Post-World War II to the Present

Starting in 1949, and through the 1950s and 1960s, the Army deployed MET teams to obtain meteorological data for artillery (Leviton and Hafford 1970; US Army FM 6-15(62) 1962). The complete system for the Artillery Meteorological Section included the rawinsonde set (GMD-1), radiosonde recorder, hydrogen gas inflation devices, and various other equipment (total weight of ~5400 lb [2450 kg]). Figure 1, taken from US Army FM 6-15(62) (1962), displays the major items of equipment that composed the artillery MET system as of 1962. It was "manpower-intensive", needing 15 personnel along with their 4 vehicles and 2 trailers. Given the scarcity of helium, balloons usually were inflated with hydrogen that was produced using calcium hydride in a large drum filled with water. Manual methods were used to process the data.

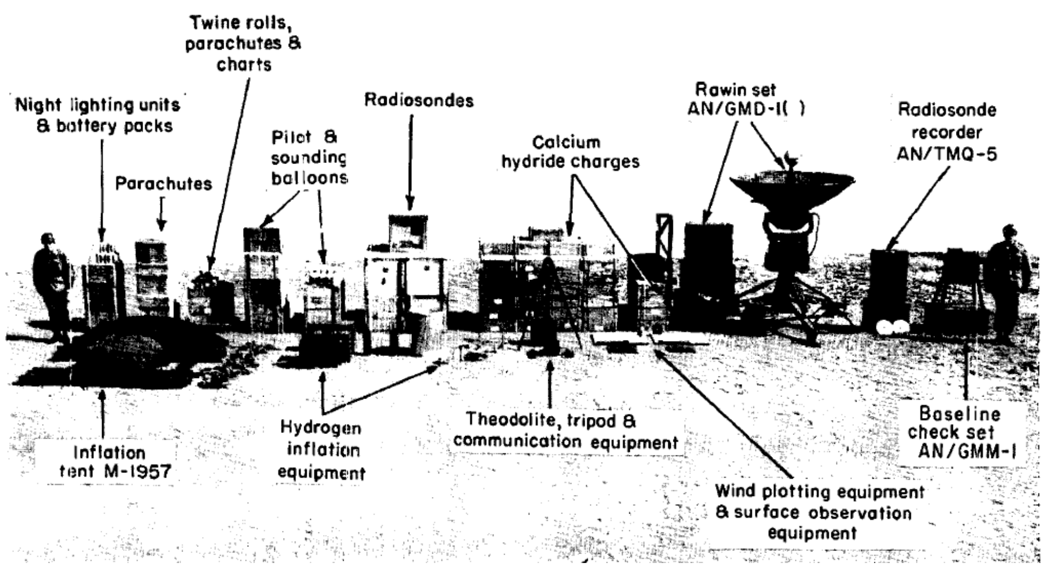

Fig. 1 Major items of equipment for the artillery meteorological section. From US Army FM 6-15(62) (1962).

The GMD-1-based system underwent several modifications following its introduction and was finally replaced in the early- to mid-1980s by the Meteorological Data System (MDS). The MDS equipment was carried on three

5-ton trucks plus trailers. However, fewer personnel were needed. Although the onboard computer system was very limited by today's standards, it eliminated much of the need for manual processing and was considered a step forward. Starting in the early 1990s, it was replaced by the Meteorological Measuring Set (MMS), which contained much the same capability but with upgraded equipment carried by 2 High-Mobility Multipurpose Wheeled Vehicles (HMMWVs), plus trailers including a generator, and needed only 5 or 6 personnel. That system in turn was replaced by the Meteorological Measuring Set–Profiler (MMS-P), which represented a major departure from previous artillery MET systems. MET output in the form of various messages such as the Computer Meteorological Message (METCM) was extracted from a database produced by an onboard mesoscale model, the 5th Generation Pennsylvania State University/National Center for Atmospheric Research Mesoscale Model (MM5; Grell et al. 1995). Schroeder et al (2006) and Stauffer et al (2007) describe the model as used in the MMS-P. US Army FM 3-09.15 (2007) describes the operation of the MMS and MMS-P, and includes discussions on "Elementary Meteorology," effects on artillery, and aspects of meteorological models. The MM5 was initialized with data from a large-scale model (the Navy Operational Global Atmospheric Prediction System [NOGAPS]) sent from the Air Force Weather Agency (AFWA), now known as the 557th Weather Wing (557 WW). This capability also permitted more accurate extraction of MET conditions for potential target areas, in addition to data for computation of trajectories. The MMS-P needed 2 standard HMMWVs and a trailer, and 6 personnel. A radiosonde capability that used helium for balloon inflation was retained for a few years, but later was removed. The removal of the balloon reduced the logistics of the system to 1 vehicle, plus a small trailer, and even fewer personnel.

Given the advances in computer processing over the several years after its fielding, the opportunity arose to replace the 3 computers on the HMMWV with a laptop running the same model and other related software known as the Computer, Meteorological Data–Profiler (CMD-P). This replacement removed the need for the vehicle and trailer. The remaining Army MET personnel were transferred to other positions, with the CMD-P operated by personnel who have other primary duties. In addition the Global Forecast System (GFS), also sent from the AFWA/557 WW, replaced the NOGAPS as the large scale initialization model. A few years later, an upgraded version, the Profiler Virtual Module (PVM), employed the Weather Research and Forecasting (WRF; Skamarock et al. 2008) model instead of the MM5, plus some additional upgrades, running on a newer laptop. The PVM as an operational system is briefly described at http://asc.army.mil/web/access-acq-profiler-meteorological-system-aligns-with-armys-fire-support/. The current PVM is able to process large scale initialization data from the Air Force's

Global Air Land Weather Exploitation Model, or GALWEM (the UK Met Office's Unified Model with some modification), which replaced GFS at the 557 WW. The Marines also adopted the MMS-P, and assisted the development of the later CMD-P and PVM, and fielded them. An additional capability was developed for the Marines in that a handheld device similar in size to a smartphone could produce meteorological messages up through the lower troposphere using input from a pibal and other sources. Future plans include putting the PVM software on a server in the operations center and running it as a virtual machine. Figure 2 illustrates the progression from the MMS-P to the current PVM and its potential form as a virtual module.

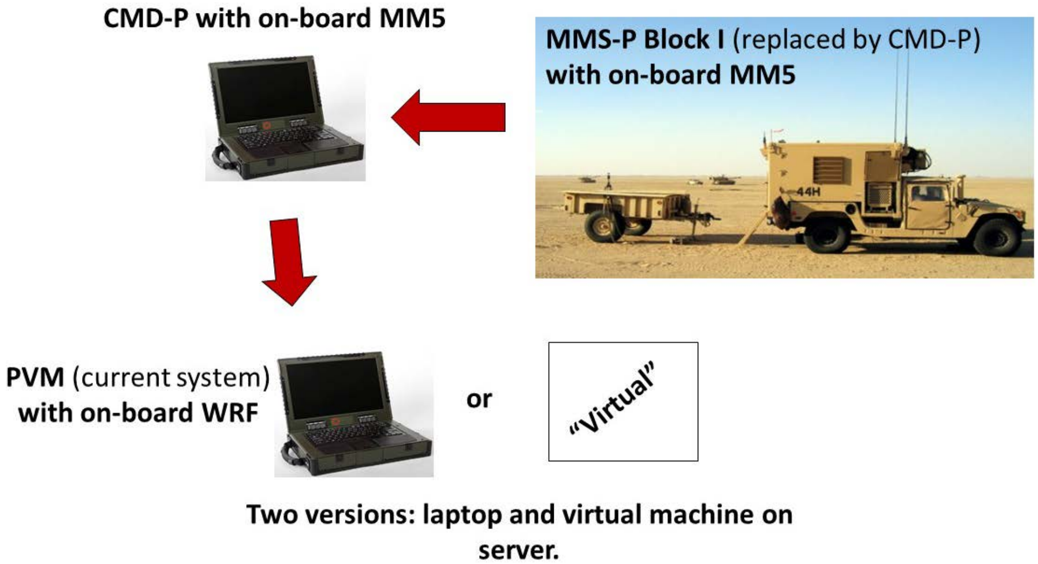

Fig. 2 Chart illustrating the progression from MMS-P to PVM and potentially running on a virtual machine

5. Conclusion

Military meteorology in the US and elsewhere has made significant advances since early in the 20th century. WW1 saw the introduction of many of the concepts for measurement and, to a lesser extent, forecasting that are in use today. Further advances were made in the years leading up to and during WW2. Nevertheless, the last 2 decades have seen greater advances in artillery meteorology than in all the previous decades back to WW1. This report briefly noted some of the more significant advances in artillery meteorology in the US and some parallel ones noted in a UK publication.

6. References

1. Grell GA., Dudhia J, Stauffer DR. A description of the fifth-generation penn state/NCAR mesoscale model (MM5). Boulder (CO): National Center for Atmospheric Research (US); 1995. Report No: NCAR/TN-398+STR; 122 pp.

2. Harper K. Weather by the numbers: the genesis of modern meteorology. Cambridge (MA): MIT Press; 2008. 39 pp.

3. Headquarters, Department of the Army. Tactics, techniques, and procedures for field artillery meteorology. Washington (DC): Headquarters, Department of the Army; 1962. Field Manual No.: FM 6-15(62). 355 pp.

4. Headquarters, Department of the Army. Artillery meteorology. Washington (DC): Headquarters, Department of the Army; 2007. Field Manual No.: FM 3-09.15/Marine Corps MCWP 3–16.5. 270 pp.

5. Jones B. Using forecast meteorological data to reduce the artillery error budget. 26th Int’l Symposium on Ballistics; 2011; Miami, FL.

6. Leviton R, Hafford W. General concepts in rawin systems. In: Teweles S, Giraytys J, editors. Meteorological Observations and Instrumentation. Meteorological Monographs, American Meteor Soc. 1970. p. 383–391.

7. Pedgley D. Meteorology in World War One. Weather. 2006;61(9):264 (doi:10.1256/wea.26.06).

8. Schroeder AJ, Stauffer DR, Seaman NL, Deng A, Gibbs AM, Hunter GK, Young GS. An automated high-resolution rapidly relocatable meteorological nowcasting and prediction system. Mon Wea Rev. 2006:1237–1265.

9. Skamarock WC, Klemp JB, Dudhia J, Gill DO, Barker DM, Duda M, Huang XY, Wang W, Powers JG. A description of the advanced research WRF version 3. Boulder (CO): National Center for Atmospheric Research (US); NCAR Tech Note 475. 125 pp. http://www2.mmm.ucar.edu/wrf/users/docs/arw_v3.pdf.

10. Stauffer DR, Deng A, Hunter GR, Gibbs AM, Zielonka JR, Tinklepaugh K, Dobek J. NWP goes to war. 22nd Conf. on Weather Analysis and Forecasting/18th Conf on NWP; 2007; Park City, UT.

11. Wahl D. 2006 Increasing range and lethality of extended-range munitions (ERMS) using numerical weather prediction (NWP) and the AUV workbench to compute a ballistic correction (BALCOR) [Thesis]. Naval Postgraduate School; 2006. 116 pp.

List of Symbols, Abbreviations, and Acronyms

AFWA	Air Force Weather Agency
CMD-P	computer, meteorological data – profiler
GALWEM	global air land weather exploitation model
GFS	global forecast system
HMMWV	High-Mobility Multipurpose Wheeled Vehicle
MDS	meteorological data system
MET	meteorological
METCM	computer meteorological message
MMS	meteorological measuring set
MMS-P	meteorological measuring set – profiler
NOGAPS	Navy Operational Global Atmospheric Prediction System
PVM	profiler virtual module
RAOBs	radiosonde observations
UK	United Kingdom
US	United States
WRF	weather research and forecasting
WW1	World War I
WW2	World War II

1 (PDF)	DEFENSE TECHNICAL INFORMATION CTR DTIC OCA
2 (PDF)	DIR ARL IMAL HRA RECORDS MGMT RDRL DCL TECH LIB
1 (PDF)	GOVT PRINTG OFC A MALHOTRA
1 (PDF)	DIR USARL RDRL CIE J L COGAN